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CAP payments and agricultural GHG emissions in Italy. A farm-level assessment

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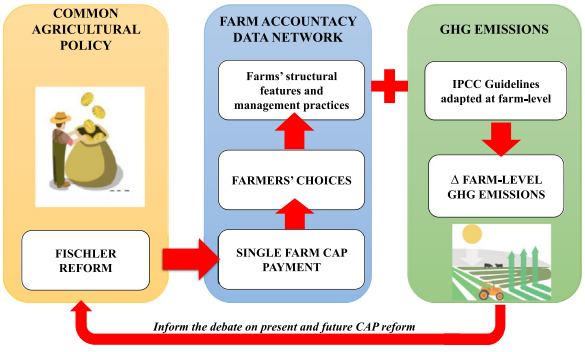
HIGHLIGHTS

- Agriculture accounts for more than 10% of total CO_2 emissions in the EU-28 area.
- We estimate the CAP Fischler Reform possible impact on agricultural GHG emissions.
- The analysis is carried out at micro level using farm level data.
- CAP expenditure had a role in the evolution of the farm-level emissions.
- Results are informative for the debate on future CAP reforms.

GRAPHICAL ABSTRACT


COMMON AGRICULTURAL POLICY
FISCHLER REFORM
FARM ACCOUNTACY DATA NETWORK
Farms' structural features and management practices
FARMERS' CHOICES
SINGLE FARM CAP PAYMENT
GHG EMISSIONS
IPCC Guidelines adapted at farm-level
Δ FARM-LEVEL GHG EMISSIONS
Inform the debate on present and future CAP reform

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ABSTRACT

The Common Agricultural Policy (CAP) is an important external driver of European agricultural production. Nowadays and in its envisioned future structure post-2020, the CAP has among its major objectives tackling climate change, for what concerns both adaptation and mitigation strategies. However, little is known about the link between past CAP reforms and agricultural greenhouse gases (GHG) emissions. This paper investigates the possible role played by the Fischler Reform (FR) on the agricultural GHG emissions at the farm level. The FR represents a major CAP reform for which data availability allows an ex-post analysis about its actual impacts. The empirical analysis concerns a balanced panel of 6542 Italian Farm Accountancy Data Network observed over years the 2003–2007. Multinomial Logit models are estimated in sequence to express how the farm-level production choices, and the respective emissions, vary over time also in response to CAP expenditure. Results suggest that CAP expenditure had a role in the evolution of the farm-level emissions, though the direction of this effect may differ across farms and deserves further investigation.

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1. Introduction

The Common Agricultural Policy (CAP) is the oldest and still the most relevant, in terms of expenditure, EU policy. In its never-ending reform process the CAP has undergone a substantial redefinition of its

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overall objectives with a growing emphasis put on the environmental implications of the agricultural activity (European Commission, 2013). This renewed justification of the CAP towards environmental requirements is confirmed and even reinforced by the CAP reform currently in place, i.e., the 2014–2020 CAP Reform. It is clearly stated that a new greening architecture of the CAP is needed since "given the pressure on natural resources, agriculture has to improve its environmental performance through more sustainable production methods". In particular, "farmers also have to adapt to challenges stemming from changes to the climate by pursuing climate change mitigation and adaption actions" (European Commission, 2013: 6).

To pursue such new architecture, both pillars of the CAP have been significantly modified in order to introduce further voluntary and mandatory measures conditioning the financial support to specific production choices implying better environmental performances and, more specifically, lower greenhouse gases (GHG) emissions. Among the different environmental pressures implied by agricultural activity, GHG emissions have become a major concern at both the global and the European level (Council of the European Union, 2013a, 2013b).

Also, the current debate on the post-2020 CAP reform clearly pushes this greening justification and architecture forward (Erjavec, 2017; Matthews, 2017). On November 2017, the European Commission presented a communication outlining ideas on the future of food and farming, to better clarify where the current policy can be simplified and modernised (European Commission, 2017). In this communication, it is reaffirmed that facing climate change and preserving natural environment represent the most important challenges facing the EU and the CAP is given an enhanced role in this context, both in adaptation and mitigation grounds. The future CAP objectives would fulfil not only the legislative obligations deriving from 2030 Climate and Energy framework (European Commission, 2014), but also the already agreed international objectives and targets on the environment, climate change (with the Paris Agreement), and several Sustainable Development Goals (SDGs) (European Commission, 2017).

It is worth noticing that such substantial reorientation of the CAP objectives and support is grounded on the belief that changing the way support is delivered substantially affects the choices and behaviour of farmers thus considerably affecting their production and environmental performance. This belief cannot be evidently assessed on the current reform, as it is still under way and data about the consequent farm choices are mostly lacking. Nonetheless, in order to contribute to the debate over the present and the future CAP on these aspects, an *ex post* assessment on the actual impact of CAP measures aimed to improve agricultural emission performance can be definitely performed on past reforms and, in particular, on what is considered the most radical change of the CAP since its beginning, that is, the 2003–2005 reform also known as Fischler Reform (FR). The FR was expected to have a relevant and positive impact on agricultural emissions due to the decoupling of the first pillar's payments and to the respective mandatory cross-compliance,[1] as well as to several second pillar measures associated to the reduction of agricultural GHG emissions (European Commission, 2014).[2] However, although several studies have performed an ex-ante evaluation of the impact of the FR on agricultural GHG emissions (Shrestha et al., 2007; Dixon and Matthews, 2006), there is almost no empirical literature on the ex-post evaluation, i.e. on the actual impact of the reform.

Nevertheless, data about the farm-level response to this reform are now complete and large enough (especially in terms of time coverage) to allow for a rigorous assessment of the direction and magnitude of this response. CAP evidently is an important external driver of European agriculture and it is commonly agreed that this policy has had a preeminent role in shaping agricultural production and its consequent environmental impacts across Europe.

The objective of the present study is thus to provide such ex-post analysis on whether there is any evidence of a correlation between farm-level CAP support delivered after the FR and the respective GHG emission. In fact, the paper does not aim to investigate any causal relationship between CAP payments and GHG emissions, but only whether these payments are associated to a significant change of emissions. The main assumption underlying the adopted approach is that the farmers do not modify the GHG emissions intentionally as response to a change in the CAP support. This latter induces them to change their input or output mixes and this then reflects in a (positive or negative) variation in the level on GHG emissions.

The paper is structured as follows. Section 2 discusses the policy context, overviews the relevant literature on the topic and presents the overall rationale of the study. Section 3 analyses the main issues arising in the estimation of agricultural GHG emission at the farm level and the approach here adopted. Section 4 describes the FADN sample here used while Section 5 presents the adopted empirical specification and the consequent estimations. Section 6 concludes drawing the main policy implications.

2. The CAP and GHG emissions

2.1. The policy context

In Europe, and in Italy, the agricultural sector is the second largest source of GHG emissions in 2014 (with respectively 10.2% and 7.2% of total emissions), after the energy sector (76.8% and 81.2%) (ISPRA, 2016; EEA, 2016), though they have already achieved a significant reduction since 1990 at both EU (−20.6%; EEA, 2016) and Italian level (−16.2%; ISPRA, 2016). The European strategy for the agricultural sector to tackle climate change is represented by the Effort Sharing Decision (ESD. Dec. n. 406/2009/EC) that establishes annual binding GHG emission targets for sectors,[3] like agriculture, not included in the EU Emissions Trading System (ETS) for the Member States for the period 2013–2020. The EU-level reduction target is −10% in 2020 (from the 2005 baseline) and each Member State is expected to contribute to this effort in different percentages, according to its GDP per capita. Italian target is −13%. More recently, the policy framework for climate and energy in the period from 2020 to 2030 sets even more ambitious targets. For the non-ETS sectors the target is of a 30% reduction (compared to 2005 baseline) (European Commission, 2014).[4]

Policies expected to play a role in the achievement of these emission reduction targets in agriculture are various. On the one hand, several EU environmental policies (e.g., the Nitrates Directives and the Renewable Energy Directive) may have a direct influence on agricultural activities. On the other hand, the CAP itself plays a major role. In fact, most CAP measures have the potential to influence greenhouse gas emissions from agriculture even if they are not directly aimed to GHG mitigation. In analysing the European Environment Agency (EEA) database on climate change policies and measures,[5] van Doorn et al. (2012) acknowledge that, within the agricultural sector, the key EU or Member States policies are some second pillar (i.e., Rural Development Policy, RDP) measures not specifically aimed at climate change mitigation.[6] Thus,

[1] Cross compliance makes direct payments conditional to the respect of Statutory requirements from 19 Community Acts, including 5 environmental Directives and maintenance of Good Agricultural and Environmental Conditions (GAEC).

[2] In particular: measures fostering compliance with environmental legislative requirements (e.g. Water Framework Directive payments); measures supporting the provision of environmental services on a voluntary basis (agri-environmental measures); measures related to animal welfare or to afforestation (Council Regulation (EC) 1257/1999).

[3] These sectors are: transport, buildings, agriculture and waste.

[4] The Commission just states that agriculture, land-use, land-use change and forestry should be included in the GHG reduction target for 2030, specifying that further analysis will be undertaken with the aim of assessing the mitigation potential and most appropriate policy approach (European Commission, 2014).

[5] Available at the following url: http://pam.apps.eea.europa.eu/ (accessed 15.05.2017).

[6] For instance, they are likely to have a significant positive effect on agricultural GHG emissions by introducing anaerobic digesters or reducing the amount of nitrogen inputs.

the CAP likely is the main driver of emission trend in the agricultural sector, even when it has not a climatic objective *stricto sensu*.

In the last 25 years, the subsequent CAP reforms have increasingly directed the support towards more environmentally sustainable agricultural activities. This "greening of the CAP" started with the McSharry reform (approved in 1992), through the introduction of semi-decoupled direct payment and of the agro-environmental programmes. Additional environmental support was then provided by the Agenda 2000 reform (approved in 1999), with the introduction of voluntary eco-conditionality and the formal setting of the second pillar of the CAP, the RDP. In this context, agri-environmental measures became the only compulsory component of the Member States' RDP. But it is with the FR that the greening of CAP allegedly reached the point of no return. The FR was expected to have a major positive impact on environmental externalities of agriculture through the combination of full decoupling of the first pillar support and mandatory cross-compliance. Moreover, several second pillar measures were expected to bring about a reduction of GHG agricultural emissions (namely: measures supporting compliance with environmental legislative requirements; agri-environmental measures; measures related to afforestation) (Baldock et al., 2007; EEA, 2012: 439; EEA, 2016; Zezza et al., 2017).

The strong impulse provided by the FR in the direction of an extensification of production has been finally confirmed and even reinforced with the design of current the CAP (programming period 2014–2020) (Council of the European Union, 2013a, 2013b). The emphasis on environmental objectives is, at least in the underlying political intentions, reaffirmed with the major novelty that now the climate action, together with the sustainable management of natural resources, has become one of the three key objectives of the reformed CAP itself. In the first pillar, a significant part (up to 30%) depends on the fulfilment of specific environment-friendly practices (Greening Payment). In the second pillar, the climate action has become a cross-cutting objective of the whole RDP and the main goal of two specific priorities (namely, priorities 4 and 5).

A final change underwent by the CAP in the last decade and that is expected to bring about a significant impact on the sectoral GHG emission is the abolition of the milk quota system. In fact, it was already decided in the Health Check (approved in 2008) that dairy quotas had to expire in 2015 (European Commission, 2013: 5). This imply that dairy production within the EU is no more subject to quantitative limitation. In principle, this was expected to induce a negative effect on GHG emission due to the increase of the number of dairy cows. As a matter of fact, however, the actual influence of the quota abolition on emission performance is more complex as it may have implied a significant reorganization (thus, either intensification or extensification of breeding) with a hardly predicable impact on emissions.

2.2. A brief literature review

The literature on the ex-post assessment of the impact CAP on agricultural GHG emissions is quite poor mostly because in the past CAP reforms emission mitigation was not a major objective and farm-level data in this respect were neither available nor reliable. On the contrary, the current (2014–2020) CAP reform declares the reduction of emission as a major policy objective. Therefore, a large body of studies is now emerging also with specific reference to the Italian context. From these ex-ante impact studies, it emerges that the new Greening Payments are not expected to have a major impact on land use (Solazzo and Pierangeli, 2016; Cimino et al., 2015; Solazzo et al., 2015) with only a limited environmental benefit mostly due to the reduction of the use of chemicals (mainly nitrogen, N) and in the increase of crop diversity (Cortignani and Dono, 2015, 2018). More specifically, in terms of GHG emissions, Solazzo et al. (2016) foresee a very modest likely reduction of −1.5% due to the introduction of the Greening Payments in four Northern Italian regions. On the contrary, the reintroduction of some coupled payments and the milk quota abolition are likely to generate an increase in productions implying a higher GHG emission level (Cortignani et al., 2017; Cortignani and Dono, 2018).

All these studies use FADN farm samples and, above all, they all use these farm-level data to perform an ex-ante assessment (i.e., simulations) of the CAP reform impact on production choices and emissions, as ex-post (i.e., real) farm-level evidence is not available yet. Despite their complexity, these simulation/optimization models may fail in fully capturing the whole set of internal and external constraints actually limiting the adaptation of farms at least in the short term. As a consequence, it could be argued that these models tend to overestimate the impact of CAP reforms on farms' choices and performances. In fact, this conclusion seems to be supported with reference to past CAP reforms whose real ex-post impact are now fully available. In particular, some recent works have emphasised that, despite its radicality, the farms response to the FR has been less relevant than expected and, above all, it has been substantially different across different farm typologies (Esposti, 2017a, 2017b). This conclusion about the possible overestimation of the expected response of farmers and the relevance of farms' heterogeneity seems to hold true also in the specific case of second pillar's environmental measures (Chabé-Ferret and Subervie, 2013).

Therefore, it seems of major interest to use past CAP reforms, say the FR, as a sort of laboratory to assess the real response of farm emission performance to the greening of CAP and, therefore, to what extent the ex-ante impact studies might overestimate the actual effectiveness of the current and of the post-2020 CAP reforms.

2.3. The rationale of the study

The present analysis aims to contribute to this ex-post empirical evidence using the FR as a case study. This empirical study analyses the relationship between farm-level CAP payments and GHG emissions on the basis of two main assumptions: emissions are an unintended side-effect of some agricultural productions; the farmer is a private agent taking decisions to maximize her/his own utility.

On the first aspect, it is wort reminding that negative and positive externalities of the agricultural production processes usually are not intended outcome for farmers' decisions but their unintended consequence due to the technical jointness implied by these processes.[7] GHG emissions are a typical example of this: most farmers are actually unaware of their emission performance as GHG are the unintended and unobserved effect of some of their production choices. This motivates why policies significantly affecting farm emission performance might have a completely different target, emissions being only their side-effect. In this respect, many studies (see Baldock et al., 2007, among others) have already shown that CAP measures not directly aimed at addressing the environmental sustainability of agriculture (e.g. the introduction/abolition of milk quota), in fact, significantly affected it.

The second hypothesis implies that, since farmers behave as utility maximizing private agents, they take decisions disregarding the consequences not entering their own utility function, therefore disregarding the abovementioned unintended effects. This is the case for most environmental externalities not directly addressed (i.e., supported or penalized) by the policy (Picazo-Tadeo et al., 2011). Therefore, the rationale underlying the present analysis is that CAP measures do not directly affect GHG emissions. They rather affect those farmers' decisions (on both input and output side) whose unintended effect is a change in their GHG emission performance.

A major consequence of agricultural GHG emissions being an unintended effect, is that they are also unobservable at the farm level. Since they are non-point sources of pollution, they can only be computed indirectly. To do this, the Intergovernmental Panel on Climate

[7] "Joint production refers to situations where a firm produces two or more outputs that are interlinked so that an increase or decrease of the supply of one output affects the levels of the others" (OECD, 2001: 16).

Change (IPCC) approach is based on a linear relationship between activity data (AD) multiplied by an emission factor (EF). AD are the main input used in agriculture (e.g. fertilizers, land, fossil fuel, livestock heads, etc.), while EF can vary depending on production practices and management conditions. The assumption here is that farmers' production choices unintentionally affect both AD and EF used to calculate GHG emissions. In fact, the impact of these choices on AD is expected to be higher than on the EF as decreasing AD (e.g. reducing the number of animals) implies removing its relative GHG emissions, while improving EF means reducing them only by a limited percentage.[8] Coderoni (2010) concludes that over the period 1990 to 2007, the EU policy interventions and reforms that mostly affected agricultural GHG emissions have been those CAP measures concerning dairy and meat (mostly beef) production that induced a substantial reduction of the number of animals.

GHG emission performances can be viewed as unintended consequence of CAP measures even when considering second pillar (RDP) measures with an explicit environmental target. In particular, agri-environmental measures stimulate actions with an implicit but relevant emission mitigation potential.[9] Among these measures here we concentrate on the following: F1-Low environmental impact; F2-Organic Farming; H-Afforestation-costs of planting; H-Afforestation-maintenance; H-Afforestation-loss of revenue; I1-Afforestation non-agricultural areas; *E*-Less Favourite Areas (LFA); I6-Reforestation for natural disturbances. Table 1 presents the expected impact of these policy instruments implied by the FR on the AD of EF, thus on farm-level GHG emissions.

Table 1
Likely impact of FR CAP instruments on GHG emissions.

Measures	Actions	Expected impact on GHG mitigation
Decoupling	Reduced incentives for intensive production (less fertilizer use, extensification); Farmers more careful to market signals	+++
Modulation	Structural measures	+/++
	More resources for rural development (agri-environmental measures, training, etc.)	+
Cross-compliance	Soil erosion reduction	+
	Better management of soil organic carbon	+
	Reduction of fertilizers use	+
Set aside*	Reduction of fertilizers use	+/++
	Potential carbon sequestration improvement	+/++
Energy crops	Potential fossil fuel replacement, but higher emissions from land conversion	?
Agri-environment	F1-Low environmental impact	+++
	F2-Organic Farming	++
	H-Afforestation-costs of planting	+++
	H-Afforestation-maintenance	+++
	H-Afforestation-loss of revenue	+++
	I1-Afforestation non-agricultural areas	+++
	E-Less Favourite Areas (LFA)	+
	I6-Reforestation for natural disturbances	+++

* until 2008.
+/++/+++ = expected impact low/medium/high, respectively; ? = uncertain.
Source: authors' elaboration on Coderoni (2010) and EEA (2006).

3. Agricultural GHG emissions at the farm level

Following the logic presented above, the first step to perform an assessment of the relationship between CAP payments and GHG emissions consists in the reconstruction of the unobserved farm-level emission levels. Even though internationally agreed protocols are lacking at the micro-level, we can still largely rely on the macro-level international standards. Monitoring, reporting and verification of GHG emissions is a fundamental step of every policy framework for GHG abatement. To fulfil the commitments made under the UNFCCC (United Nations Framework Convention on Climate Change) and the European Union's Greenhouse Gas Monitoring Mechanism, every Member State should prepare the annual National Inventory of emissions and removals of GHG, which is the official tool for monitoring commitments (made, in Italy, by the Institute for Environmental Protection and Research. ISPRA, 2016).

Within the UNFCCC, the IPCC, that is the scientific and technical body of the Convention, has been given the role to establish a common methodology to estimate emissions and removals from all sectors, using simple and available data, because they must be adopted all over the world for reporting purposes. According to the estimation made with this methodology, IPCC (2014) finds that the agriculture, forestry and other land uses (AFOLU) sector represents the 24% of global GHG emission in 2010.

Despite their relevance, the accounting of agricultural GHG emissions remains one of the most challenging issues in this field. In fact, agricultural GHG emissions are a typical example of non-point source pollution, so this kind of emissions must be computed indirectly. The common methodology to perform this indirect computation is provided by the IPCC (2006) guidelines that, as already mentioned, represent a widely applicable and, above all, internationally recognized standard. Nonetheless, this standard, and the consequent protocols and applications refer to aggregate (macro) data (Coderoni and Esposti, 2013, 2014). The novelty in the present paper, is that the IPCC methodology is adapted and applied at the farm (i.e. micro) level.[10]

The basic IPCC approach obtains GHG emissions by multiplying AD by an EF, whether default, country specific or region specific. For this study, we have used Farm Accountancy Data Network (FADN) as AD and default or country specific EF (ISPRA, 2011) to reconstruct methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions for all the emission sources listed in Table 2 and grouped in the following five emission categories: livestock, cultivation, land use, fuel and fertilizers.[11] The sum of all these emission sources gives what we have defined, for the purposes of this study, the Carbon Footprint (CF) (see Coderoni et al., 2013, for further details on the methodology and EF used).

A major problem when using the FADN survey to derive GHG emissions, is that the data collection is not aimed at calculating this environmental indicator and some information are thus missing. To overcome this information gap and compute the farm-level CF, some assumptions have been made. Major assumptions regard the following CF categories.

For what concerns rice emission, at present, FADN information does not include data on rice cultivation methods, so it is not possible to distinguish between single and multiple aeration. Considering that the vast majority of rice area in Italy is cultivated under the multiple aeration regime, the relative EF has been used (ISPRA, 2011); this assumption

[8] For some Italian livestock production chains, Coderoni et al. (2015) find that the greatest mitigation potential for a single action reaches only 15% of reduction (for the biogas plant).

[9] Using a sample of Spanish farmers operating in the rain-fed agriculture, Picazo-Tadeo et al. (2011) find that CAP agri-environmental programs seem to be an effective policy to improve farms' eco-efficiency. Analysing the performance of different types of farming in England (arable, lowland livestock, and upland livestock), Westbury et al. (2011) find that agri-environment scheme participation was an important factor only for arable farms.

[10] The choice of adapting the IPCC methodology at farm level could be questioned, however, not only they represent an internationally recognized standard, but they also provide a widely applicable default methodology used also by relevant empirical literature on this field (De cara et al., 2005; Dick et al., 2008; Perez Dominguez et al., 2009; Solazzo et al., 2016. See Colomb et al., 2013 for a review of calculators for landscape scale GHG assessment for agriculture).

[11] To express all these emissions in a unique unit of measure, i.e., total CO_2 equivalent (CO_{2e}), any different GHG is multiplied by its Global Warming Potential (GWP). In this work, we refer to GWP as defined in the Second assessment report by the IPCC (i.e. 21 for CH_4 and 310 for N_2O).

Table 2
Summary of GHG emission sources considered for each CF category and the respective FADN activity data used.

CF category	Emission sources	FADN data
CF Livestock	N_2O manure management	Animal numbers
	CH_4 manure management	Animal numbers
	CH_4 enteric fermentation	Animal numbers
CF Cultivation	CH_4 rice cultivation	Rice area (UAA)
	N_2O Biological N fixation	N-fixing crop area
	N_2O Crop residues	Crop area (UAA) or crop yield
	N_2O Atmospheric deposition	Animal numbers
	N_2O Leaching and run-off	Animal numbers
CF Fertilizer	N_2O Use of synthetic fertilizers	Fertilizers expenditure
	N_2O Atmospheric deposition	Fertilizers expenditure
	N_2O Leaching and run-off	Fertilizers expenditure
CF Fuel	CO_2 Energy	Fuel expenditure
CF Land use A and B	CO_2 Forest land	UAA
	CO_2 Cropland	UAA
	CO_2 Grasslands	UAA

might evidently represent a slight overestimate of the respective emissions.

The CF deriving from fertilizers consumption has been estimated using total fertilizers expenditure at farm level, as FADN survey did not collect information on quantities of N during the period analysed. Both direct and indirect emission (due to N leaching and run-off) are accounted for. The estimation assumes that 1 euro of expenditure in fertilizers (N, P or K) at constant 1995 prices, corresponds to the same amount of N input as derived from the Agrefit dataset (Rizzi and Pierani, 2006). According to this assumption, every euro spent on fertilizers corresponds to 0.54 Kg of nutrients (N, P or K).[12]

The CF of fuel has been estimated using total agricultural fuel expenditure at farm level, by dividing for the average price of agricultural diesel observed over time and across different Italian provinces (available online).

The CF of land use has been calculated in two alternative ways, to reflect the different assumptions made on the underling methodology. The first approach (CF Land Use A) has been obtained adapting ISPRA (2016) Implied Emission Factors multiplied by the UAA cultivated with respective crops. More in detail, land uses have been distinguished in: forest, other wooded land, perennial woody crops, plantation and coppices.[13]

However, since the value obtained with this approach for perennial wood crops is negative (thus, represents a source of emissions)-for the value of this carbon (C) stocks at maturity-a different EF has been used, to consider that perennial crops give both with soils and biomasses a higher contribution in C sink than annual crops. This second approach (CF Land Use B) considers a positive value for perennial wood crops using, in the absence of country specific values, an average value of 10 t C ha-1 (for carbon stock at maturity), deduced by the values adopted in Spain, suggested by Joint Research Centre (JRC) experts to ISPRA considering a cycle of 20 years (ISPRA, 2016: 228).

The farm-by-farm reconstruction of the emission levels across a balanced panel dataset allows observing the variation of emission performance across space, i.e. across the heterogeneous farming types (in terms of farms' characteristics and specialization, geographical localization, economic dimension, etc.) and over time. Evidently, the extreme variety of environmental and management systems in Italian farming represents the main problem when computing these farm-level emissions. Thus, the developed methods are expected to be strongly connected to the different production processes and to the use of activity data that are strictly and properly linked to emission production.

An important characteristic of the IPCC approach to agricultural emission computation is that it refers to the production stage while disregarding the consumption one. This means that it is the "process level", not the "product level", emission that counts. This approach seems suitable to carry out a sectoral analysis and inform sectoral policies. In fact, it estimates the emissions that occur within the "farm gate", i.e., those on whose determinants the farmer has a "direct" control, while it disregards the emissions occurring in the downstream supply chain of the respective agricultural products.

4. The FADN sample

As the objective here is to assess the evolution of the GHG emission and of the CF in Italian farms, with specific attention on the role played by the FR of the CAP, the sample under investigation has to satisfy some specific requisites. Firstly, it must be a balanced panel not just a cross-sectional sample and must contain all the needed information to compute the GHG emission and CF at the farm level as well, as all the other farm-level variables that might significantly affect these performances. Finally, with respect to the time dimension, sample farms have to be observed over the pre and post-treatment periods (i.e. before and after 2005, which is the year of the implementation of the reform in Italy). These conditions can be met by extracting a constant sample of farms yearly observed over the pre and post-2005 period. This balanced panel is pulled out from the FADN (RICA) database and contains 6542 farms observed over years 2003–2007. Though FADN database also covers years prior to 2003, the sampling and data collection procedures and criteria do not allow reconstructing a balanced panel backwards. Moreover, adding years 2000–2003 in the pre-treatment period can be troublesome as they may still incorporate some effects of the previous CAP reform (namely, Agenda 2000). Thus, a 2001–2007 comparison, for instance, would overlap different CAP reforms and would mix-up different policy treatments. Year 2008 could also be added but some significant changes in FADN data collection would make year-by-year comparison more difficult. Moreover, the huge price turbulence observed in agricultural markets in 2008 (Esposti and Listorti, 2013) suggests particular caution in adding this year to the post-treatment period. Farmers' behaviour, as well as farms' performance, might be strongly affected by this price bubble and this year could confound permanent responses due to policy treatment with those temporarily induced by peculiar market conditions.

Table 3 reports the evolution of per farm average CF from 2003 to 2007 distinguishing the total emission performance among its five emission categories.

Several most important regularities emerge. First, some categories are clearly dominating the total amount of emissions while others are, in fact, negligible. In the former case, we can mention the CF associated to livestock and related activities, representing by large the most important source of emission at the farm level. Fuel and fertilizers' CF also has remarkable role. In the former case, it must be noticed that the CF of fuel is attributed to the transportation (i.e. energy) sector, rather than to agriculture, by the IPCC methodology, thus it is an aspect that it is often disregarded in the empirical studies on the agricultural contribution to the GHG (Coderoni and Esposti, 2014). In the latter case, we may appreciate how the CF associated to land use and its changes are insignificant compared to all other categories.

It is worth acknowledging that, as detailed in previous sections, the CF associated to land use here only considers the agricultural land use. So, forestry and related activities are not investigated due to the lack of appropriate and complete information in the FADN dataset in this respect (only data on poplar plantations and few other species are accounted for). Nonetheless, it remains true that these results seem to

[12] Baldoni et al. (2017), using the quantity of N applied provided by FADN dataset from 2008 to 2013, find a very similar value (0.5 Kg).

[13] For both the methodologies applied, following ISPRA (2016: 228) "the change in biomass has been estimated only for perennial crops, since, for annual crops, the increase in biomass stocks in a single year is assumed equal to biomass losses from harvest and mortality in that same year", coherently with the IPCC Good Practice Guidance for LULUCF. Land use changes have not been considered in at this stage of the methodology, if not because of changed UUA surface.

Table 3
2003–2007 evolution of the farm-level CF distinguished into the five macro categories of emissions and across different farm typologies (ton CO_{2e} per farm avg.; standard deviation in parenthesis).

Emission category:	2003	2004	2005	2006	2007	Var. 2007–2003 (%)
CF fuel	25,9	27,1	29,8	31,4	32,6	0.9
	(60,0)	(60,4)	(67,4)	(68,7)	(70,5)	(10.2)
CF cultivation	14,1	14,3	14,3	14,8	14,9	53.4
	(137,1)	(138,9)	(139,4)	(140,7)	(141,3)	(792.4)
CF fertilizers	45,0	57,6	58,8	58,3	64,8	2.1
	(157,1)	(178,2)	(198,9)	(179,0)	(190,5)	(14.5)
CF livestock	99,2	100,4	101,0	101,6	100,0	0.1
	(432,3)	(451,3)	(474,7)	(503,8)	(491,2)	(2.9)
CF land use – A[1]	−3,3E-03	−3,3E-03	−3,1E-03	−3,1E-03	−3,1E-03	0.02
	(1,4E-02)	(1,5E-02)	(1,9E-02)	(1,8E-02)	(1,8E-02)	(0.9)
CF land use – B[1]	5,8E-03	6,0E-03	6,0E-03	6,0E-03	6,0E-03	0.04
	(1,9E-02)	(2,1E-02)	(2,3E-02)	(2,3E-02)	(2,3E-02)	(0.9)
CF total – A	184,1	199,3	203,9	206,1	212,4	14.3
	(563,7)	(584,5)	(623,7)	(642,9)	(644,3)	(1087.5)
CF total – B	184,1	199,3	203,9	206,1	212,4	14.3
	(563,7)	(584,5)	(623,7)	(642,9)	(644,3)	(1087.5)
Farm typology:						
Economic size:						
ES 3–4	25.2	29.3	30.0	32.1	32.6	33.7
	(25.3)	(26.3)	(32.9)	(41.5)	(37.2)	(1697.2)
ES 5–6	120.0	132.7	134.3	120.3	124.8	0.8
	(152.9)	(154.4)	(147.2)	(128.2)	(129.1)	(4.0)
ES ≥7	887.4	932.8	992.1	965.4	989.2	0.7
	(1304.7)	(1336.5)	(1461.9)	(1473.1)	(1462.1)	(3.1)
	(432,3)	(451,3)	(474,7)	(503,8)	(491,2)	(2.9)
Correlation coeff. ES-CF	0.4	0.4	0.4	0.4	0.4	0.01
Utilized agricultural area:						
UAA < 10 ha	46.6	53.3	54.1	53.7	53.9	29.2
	(140.3)	(144.0)	(166.1)	(142.6)	(135.0)	(1576.3)
UAA 10–50 ha	145.2	157.8	157.3	158.1	166.9	0.8
	(254.7)	(251.5)	(250.6)	(252.2)	(263.6)	(2.6)
UAA > 50 ha	719.0	762.7	784.0	791.7	804.9	0.5
	(1238.4)	(1282.4)	(1374.3)	(1427.2)	(1416.2)	(1.6)
Correlation coeff. UAA-CF	0.5	0.5	0.5	0.5	0.5	0.2
Specialization:						
Crops	149.2	168.4	174.4	175.4	185.1	1.0
	(425.2)	(425.2)	(486.8)	(470.9)	(485.9)	(4.3)
Permanent crops	44.4	59.8	62.1	64.2	70.0	1.3
	(121.9)	(121.9)	(131.9)	(144.0)	(154.5)	(3.8)
Livestock	425.2	434.5	439.8	442.8	442.8	0.1
	(885.5)	(885.5)	(1002.0)	(1018.8)	(979.8)	(0.5)
Mixed crops and livestock	196.2	211.6	216.4	219.9	229.2	83.3
	(651.2)	(651.2)	(678.8)	(767.1)	(820.0)	(2696.7)

[1] CF of land use reports negative values for emissions and positive values for removals.

downsize the emphasis put on land use changes in terms of mitigation of the agricultural contribution to overall GHG emissions, at least in the way that these emissions are accounted following the IPCC methodology revision of this study.[14]

A second major evidence emerging from Table 3 consists in the very high cross-farm variability of the computed CF and that can be observed, without significant difference, in all CF categories. On the one hand, this variability can be considered the natural consequence of the large farm heterogeneity that eventually affects also the respective CF performance: indeed, both size and production specialization aspects largely affect the CF at the individual farm-level. On the other hand, a large variability prevents from deriving clear-cut conclusions on the evolution of the CF over time since, in fact, confidence intervals built around the observed average values across years are largely overlapping.

Though inconclusive, however, this evolution indicates that if we exclude the decline of land use, all CF categories experience a growth, on average, over the period under study. The largest increase can be observed for the CF of cultivations. This evidence might suggest that the decline observed in overall GHG emission observed within the Italian agriculture in the same period (−2.54%) (ISPRA, 2011) should be associated to the generalised decline of agricultural production, rather than to improvements in production processes (EEA, 2012).

Table 3 also shows the total CF per group of farms in terms of economic size (ES), physical size (UAA) and production specialization. Size evidently matters: the larger the economic and physical size of the farm, the larger is its expected CF. The correlation coefficients between the farm-level CF and the farm UAA or ES are positive and regular over time. Nonetheless, the highest growth over the 2003–2007 period is observed in smaller farms though, once again, the large variability of the computed CF makes such comparison across sub-samples largely inconclusive.

Among the different agricultural specializations, activities associated to livestock show a stabilization of CF over the period under study. This somehow confirms that the largest, if not the only, significant experience of GHG emission reduction within the Italian agricultural of the

[14] Consequently, also the relevance of the appropriate procedures to compute this component (Land Use – A vs. Land Use – B, in the present case) seems to be slightly overemphasised, thus in the following analysis, only the Land Use – A will be used to obtain the total CF, as it more coherent with the overall CF estimation methodology adopted.

last decades is essentially related to the decline of livestock activities (ISPRA, 2016), rather than to major changes in their organization and management (Coderoni and Esposti, 2014).

5. Carbon footprint and CAP expenditure

5.1. Some descriptive evidence

The possible linkage between CF evolution over time and the CAP is twofold. On the one hand, we may argue that the reform of the first pillar of the CAP approved in 2003 and implemented (at least in Italy) in 2005, has an impact on farm-level CF, both because the decoupling of support reoriented farm's production choices to market and because of the cross-compliance environmental constraints introduced therein. On the other hand, the second pillar of the CAP (2000–2006 programming period) delivers several measures that directly and indirectly concern activities and practices that affect the farm-level CF.

Table 4 reports the per farm average CF within sub-samples distinguished in terms of the intensity of the first pillar support. This intensity is expressed as the ratio between the amount of first pillar payments (FPP) received by a given farm and its gross production value (GPV). Both values are taken as the yearly averages of the year 2003 and 2007. This ratio evidently gets rid of the size effects of both FPP and GPV and considers the shift from coupled payments (years 2003 and 2004) to decoupled payments (or single farm payments) (years 2005, 2006 and 2007). Three sub-samples are compared: farms for which the incidence of FPP on GPV is almost negligible (<10%) that are almost 4500 farms; farms for which it is moderate (>10%, <30%) almost 1100 farms; farms for which it is high (>30%), almost 900.

Results show that in all sub-samples the CF increases over the period analysed but this growth is higher in farms with a lower incidence of the CAP while, on contrary, farmers depending on first pillar's support show less growing emission performance. The statistical correlation occurring between FPP and CF tends to be negative in the levels and with the variation of the CF, however, when the variation is considered, this correlation is lower.

The lower part of Table 4 shows a preliminary assessment of the linkage between second pillar's payments and the farm-level CF and its evolution. Actually, all 2003–2007 second pillar payment (SPP) refer to the 2000–2006 programming period and, therefore, to the respective RDP policy (measures), as even the 2007 payments here considered still are the finalization of the previous programming period. Two different sub-samples of farms are treated. The "With SPP" group includes farms that received, over the 2003–2007 period, at least one of the agri-environment payments listed in Table 1. The "No SPP" group includes all other farms.

Clear difference emerges between farms that received these payments and those that did not. The formers tend to have a higher CF in 2003, but a much more virtuous behaviour over time, with a strong decline that makes the CF of the excluded farms, higher than the supported ones in 2007. This also explains why the correlation coefficient between SPP and CF is positive in both 2003 and 2007 but becomes negative when the 2007–2003 variation is considered.

Table 4
Farm-level total CF (ton CO_{2e}) and first and second pillar payments, FPP and SPP (avg. 2003–2007) (per farm avg.; standard deviation in parenthesis).

Farm groups:	2003 CF	2007 CF	Var. CF 2007–2003 (%)
FPP/GPV < 10%	201.5	212.7	364.9
	(588.5)	(664.9)	(19,069.4)
FPP/GPV 10–30%	46.3	48.2	29.8
	(84.7)	(82.9)	(99.9)
FPP/GPV 30%	31.7	35.0	37.1
	(70.4)	(76.1)	(150.9)
Correlation coefficient FPP – CF	−0.10	−0.09	−0.01
With SPP	242.0	141.1	−42.0
	(812.2)	(314.5)	(84.49)
No SPP	145.0	162.0	12.0
	(461.6)	(579.3)	(16.63)
Correlation coefficient SPP – CF[1]	0.4	0.5	−0.1

[1] Only farms with SPP.

5.2. The empirical model

The aim of this study is to investigate farm-level GHG emission changes because of farm production choices possibly induced by CAP payments. Therefore, the emission changes of interest here, are those that persists in the medium-long term. Consequently, the empirical strategy adopted is to disregard those short-term (i.e., yearly) GHG emission variations that are mostly random, temporary, unexpected and therefore, unintended. The idea is that, these short-term variations are not linked to permanent farmer' choices so they are hardly linked to CAP expenditure that are expected to affect these choices. To pursue this empirical strategy, we consider the GHG emission variation over a medium-term period instead of year-by-year. So, even though we have a balanced panel dataset, our model specification is a cross-sectional model.

A first "natural" attempt to model such cross-sectional linkage between GHG emission variations and CAP expenditure consists in estimating a linear regression model, where the GHG emission variation, over the period 2007–2013, is the dependent variable and the explanatory factors included in the regression models are both farm structural features and policy variables (Table 5).

This model can produce poor statistical results mostly because a quite large part of the GHG emission performance variability may be totally random and temporary, thus unexplained by regressors. The only regressors that seem to explain the dependent performance are typology dummies (Table 6). However, this kind of data are also highly linked to policy intervention.

The alternative empirical strategy followed is to define discrete variations that are expected to more clearly identify farms that responded to CAP expenditure with production choices finally affecting GHG emissions. Alternative multinomial choice models are specified and estimated to better capture the real linkages between emission variations and CAP expenditure over the period under consideration. These kinds of models allow analysing the drivers of farmers' choices without specifying the technology (production and cost functions) that are behind these choices. In fact, as this work represents an ex-post analysis of actual farmers' choices in response (also) to policy changes, observing the real choices that farmers did, it is possible not to make assumption about technology, if not just with what is captured by the structural characteristics of farms (e.g. typologies). Thus, as the purpose of the present study was to quantify how much each driver has likely changed the farmers' choices and not how, or why, the choice changed, Multinomial Logit Model (MLM) here adopted was the most simple and effective way to capture these impacts.

At first, to evaluate the potential role of the CAP in influencing farmers' choices and thus GHGs emissions, we have estimated a MLM

Table 5
List of the explanatory factors included in the models.

Explanatory factors	Type of variable (measure)
Geographical information	Categorical (north; south; islands; centre)
Size - UUA	Categorical (small < 10 ha, 10 < medium < 50 ha, big > 50 ha)
Size - economic size	Categorical (small, medium, big)
Production	Categorical (livestock, crops, mixed)
Policy variables – first pillar payments	Continuous (FPP/GPV)
Policy variables – second pillar payments	Continuous (SPP/GPV)
Altitude	Categorical (1 = mountain; 2 = hill; 3 = lowland)

Table 6
Results of the regression model (standard error in parenthesis).

Variable	Coefficient Estimation (st. err)	
Constant	172.7***	(75.898)
UAA	−15.48	(22.319)
FPP	−0.162	(0.263)
SPP	−0.665	(1.747)
d_crop	−84.59***	(37.942)
d_livestock	−80.90	(45.483)
ES	−3.397	(24.550)
Altitude	−27.76	(20.310)
d_North	−1.631	(43.871)
d_Centre	−13.01	(52.594)
d_Islands	30.80	(45.978)
R-squared	0.0016	

assuming that the decision of the farmer, whether to reduce or increase use of input or change the output mix, depends on four categories of drivers: geographical information, farm size (both in term of UUA and ES), production mix, and policy variables (both first pillar and second pillar payments).

As already pointed out, the main assumption behind this model is that the farmer is not directly intended to modify GHG emissions, but he changes his input or output mixes in response to a change in the policy framework, and this reflects in a variation (positive or negative) in the level of GHG emissions, as they are strongly linked to activity data.

The general form of the multinomial logit model is:

$$P_{ij} = \frac{\exp\left(x_{ij}' \ \beta\right)}{\sum_{k=1}^{J} \ \exp\left(x_{iM}' \ \beta\right)}, \ \ for\ j = 0, 1, \ldots, M \qquad (1)$$

where *i* indicates the generic farm; *j* indicates the emission choice (increased, stable or decreased emissions); P_{ij} is the predicted probability of *i-th* farm to select the *j-th* GHG emission choice; β is a vector of unknown parameters and x_i a vector of explanatory variables expressing the characteristics of the i-th farm expected to influence the respective choice (Table 5).

The dependent variable is the three-category variable including the three groups obtained by dividing the sample according to their emission behaviour during the period analysed. As there is no natural ordering of the three possible outcomes, the numbering of the categories is arbitrary. We use the following: j = 1 indicates "decrease", i.e., the farm shows a decrease of GHG emissions in 2007 compared to 2003 levels that is higher than −5%; j = 2 indicates "stable", i.e., farm's emissions vary from −5 to +5% over the period analysed; j = 3 indicates "increase", i.e., the farm shows a variation of GHG emissions of >5%.

Coefficient estimates of the multinomial logistic regression are not of trivial interpretation. Therefore, in order to better assess the effect of a unit change of a particular regressor on the dependent variable (i.e., the choice), marginal effects are here estimated and discussed (Wooldridge, 2010) (Table 7).

Findings highlight significant and coherent differences between the farmers' behaviours. Geographic variables give quite clear results: farms located in the north and centre of Italy are less likely to increase emissions and coherently, they are more likely to reduce them, with respect to farms located in the south of Italy.

Looking at farms specialization, being a farm specialized in livestock, negatively affects the probability to increase emission, and consistently, positively affects the probability to decrease them.

Farms specialized in crops cultivation are more likely associated with an increase of emissions (and negatively associated with a decrease or a stabilization).

For what concerns the policy variables, that are the focus of our analysis, apparently farms more supported by first pillar are more likely to decrease their emissions over the period analysed. This result is very interesting as it would suggest the idea that the FR, which actually mainly affected the FPP, is positively associated with more virtuous farms in terms of GHG performance.

The opposite holds for SPP: receiving this kind of support is in fact more likely associated with the probability to increase emissions. This aspect, though counterintuitive-as policy instruments that should bring more environmentally sustainable behaviours are associated with less probability to decrease emission-is not so surprising. In fact, this kind of measures are often associated to farms with bigger structure, that are also more likely to increase their dimension over time, and this could partially compensate the eventual increase of farm environmental sustainability.

Thus, what should be evaluated here is whether the increase or decrease of emission over the period analysed is associated with higher or lower production per unit of emission, i.e. with higher or lower carbon productivity (CP) levels. Hence, though the model gives quite clear results, it also suggests the idea that a more complex structure of choices could exist.

To define a new set of choices, a CP index has been defined as the ratio between GPV and GHG emissions at farm level, considering the carbon (C), i.e. the GHG emissions, as an additional input to the farm's activities. CP is thus a measure of eco-efficiency: the higher the value, the more efficient is the farm, because a same amount of C (1 unit) produces more GPV. This index should help distinguishing farms that decrease (or increase) their emission due to a merely scale effect, i.e. also decreasing (or increasing) the value of production. According to this index, each of the three choices (increase, decrease or stable emission) has been divided into two sub-group of choices depending on the different trend of CP index over the period under investigation: those that show a higher level of CP in 2007 than in 2003 (i.e. CP increases) and those that show a lower one (CP decreases).

A new model with six choices, reflecting different behaviours that could probably better fit data, has thus been estimated. Results are

Table 7
Marginal effects of the MLM with 3 choices.

	Increase		Stable		Decrease	
	Coeff.	Std.err	Coeff.	Std.err	Coeff.	Std.err
UAA	−0.002	(0.009)	−0.001	(0.005)	0.004	(0.009)
FPP	−7.1E-05	(1.1E-04)	−1.1E-04	(8.5E-05)	1.8E-04*	(1.0E-04)
SPP	0.002**	(0.001)	4.5E-04	(3.4E-04)	−0.002***	(0.001)
d_crop	0.094***	(0.016)	−0.054***	(0.009)	−0.041***	(0.015)
d_livestock	−0.050***	(0.014)	0.025***	(0.008)	0.025	(0.014)
ES	−0.006	(0.010)	0.005	(0.006)	0.001	(0.010)
Altitude	0.012	(0.008)	0.004	(0.005)	−0.016**	(0.008)
d_North	−0.234***	(0.013)	0.028***	(0.008)	0.206***	(0.013)
d_Centre	−0.253***	(0.017)	0.036***	(0.010)	0.217***	(0.016)
d_Islands	0.021	(0.022)	−0.021	(0.013)	3.9E-04	(0.022)

The Independence of Irrelevant Alternatives (IIA) assumption inherent in multinomial logit models is most frequently tested with a Hausman-McFadden test (Hausman and McFadden, 1984). In this case Hausman-McFadden test cannot be used, SUEST test doesn't reject the hypothesis of IIA (10%).
Single, double and triple asterisks (*) denote significance at the 10%, 5% and 1% levels, respectively.

Table 8
Marginal effects of the MLM with 6 choices.

Choice:	GHG increase with higher CP		GHG increase with lower CP		GHG stable with higher CP	
	Coeff.	Std.err	Coeff.	Std.err	Coeff.	Std.err
UAA	0.031	(0.007)	−0.032***	(0.009)	0.003	(0.004)
FPP	−1.5E-05	(9.4E-05)	−5.5E-05	(1.1E-04)	−9.5E-05	(7.6E-05)
SPP	-4E-07**	(2.0E-07)	3.3E-07*	(1.8E-07)	8.5E-08	(6.3E-08)
d_crop	−0.002	(0.013)	0.093***	(0.016)	−0.034***	(0.007)
d_livestock	0.055***	(0.015)	−0.114***	(0.019)	0.015**	(0.008)
ES	−0.021**	(0.008)	0.014	(0.010)	0.002	(0.005)
Altitude	−0.005	(0.007)	0.015	(0.009)	0.003	(0.004)
d_North	0.058***	(0.011)	−0.281***	(0.012)	0.025***	(0.007)
d_Centre	0.069***	(0.014)	−0.315***	(0.017)	0.030***	(0.008)
d_Islands	−0.014	(0.018)	0.050	(0.020)	−0.014	(0.012)
Choice:	GHG stable with lower CP		GHG decrease with higher CP		GHG decrease with lower CP	
	Coeff.	Std.err	Coeff.	Std.err	Coeff.	Std.err
UAA	−0.004	(0.003)	0.005	(0.008)	−0.003	(0.005)
FPP	−1.3E-05	(4.7E-05)	1.8E-04*	(9.4E-05)	−2.4E-06	(6.0E-05)
SPP	6.4E-08*	(3.9E-08)	−1.1E-07	(1.9E-07)	2.5E-08	(8.4E-08)
d_crop	−0.019***	(0.006)	−0.018	(0.014)	−0.021***	(0.008)
d_livestock	0.011**	(0.006)	0.033**	(0.016)	−0.001	(0.009)
ES	0.002	(0.004)	−0.006	(0.009)	0.008	(0.005)
Altitude	0.001	(0.003)	−0.017**	(0.007)	0.003	(0.004)
d_North	0.002	(0.005)	0.187***	(0.013)	0.008	(0.007)
d_Centre	0.005	(0.006)	0.188***	(0.015)	0.022***	(0.009)
d_Islands	−0.006	(0.008)	−0.028	(0.022)	(0.012)	(0.010)

The Independence of Irrelevant Alternatives (IIA) assumption inherent in multinomial logit models is most frequently tested with a Hausman-McFadden test (Hausman and McFadden, 1984). In this case Hausman-McFadden test cannot be used, SUEST test doesn't reject the hypothesis of IIA (10%).
Single, double and triple asterisks (*) denote significance at the 10%, 5% and 1% levels, respectively.

shown in Table 8; though they are coherent with the previous estimates, still can give more interesting insights to the analysis undertaken.

For what concerns structural characteristics of the farms, statistically significant variables are those related to farm typologies and location. Farm typology results could indicate that livestock farming are the more efficient ones, as even when increase their GHG emissions, they show higher CP levels; less efficient farms seem to be the ones specialized in crops.

Geographic variables suggest that farms located in the north and centre are more likely to show more efficient behaviour as they are associated with groups showing higher CP both if they increase or decrease GHG emissions.

Looking at policy variables, interestingly, FPP seem to be more likely associated with a decrease in GHG emissions and increase in CP levels, i.e. with the more efficient behaviour, showing a sort of "decoupling" in GHG and production levels. On the other hand, we find no statistical significance of the relationship with a decrease of emissions with lower CP levels.

Receiving SPP is more likely associated with increased or stable emission and lower CP indexes. This could signal a sort of inefficiency of this kind of farms, as CP levels decrease over time and GHG emission increase or remain stable. This inefficiency seems to be reinforced by the negative relationship with SPP and the probability to increase emission, though showing higher CP.

5.3. Results discussion

MLM estimation results indicate that policy variables matter, but not necessarily in the expected direction. Some positive effect on emission performance induced by the FPP seems to occur and farms receiving more support in this respect show higher carbon efficiency (CP values). On the contrary, farms receiving SPP are more likely to show increasing (or stable) emissions and lower CP indexes. This evidence may be considered counterintuitive at least with respect to the declared objectives of the first and second pillar of the CAP. As anticipated, however, the estimated linkage between CAP payments and emissions should not be interpreted as a causal relationship. Their linkage could be rather attributed to the fact that farms "use" policy measures to support their behaviour and choices that also imply specific emission performance.

In the case of the SPP, the apparent negative effect on emissions could be due to the extensification processes brought about by SPP. At the same time, what observed for the SPP in terms of CP could depend on the fact that less efficient farms are those trying to use RDP funds just to find the path towards a more productive but also sustainable production mix. After all, individual agri-enviromental measures have been already and widely criticized (ECA, 2011) in favor of a more collective approach that only would allow for an actual improvement of environmental performances of agriculture.

The policy implications of these results are evidently relevant and, therefore, suggest caution for two major reasons. First of all, because the evidence concerning both FPP and SPP should be corroborated by further and more comprehensive (for instance on a EU scale) investigations. Secondly, and more importantly, the present study also highlights how, beside and regardless the policy support, the emission performance is highly differentiated and can be very site-specific. Therefore, farm typologies and localization strongly matter and any general interpretation about the relationship between policy support and emission performance may substantially disregard this heterogeneity and suggest misleading conclusions.

Nonetheless, these results might seem in favor of a "greening" effect of the FR since, by decoupling the first pillar support, it made farmers freer to take efficient decisions also on the environmental ground. This freedom of choice allows for a more flexible adaptation required by the abovementioned wide heterogeneity across space and farm typologies. Such a heterogeneity may eventually conflict with any one-fits-all solutions, like some second pillar measures or the Greening Payment introduced in the current programming period (European Commission, 2016).

6. Some concluding policy implications

This paper represents a first step in the direction of investigating the role of the CAP in affecting the agricultural GHG emission. Though an ex-

post evaluation of such role is possible only with respect to the past reform of the CAP (and the FR, in particular), the main interest for this investigation is that emission mitigation represents one of the main declared objectives of the current (2014–2020) CAP programming period and of the post-2020 projected reform.

In the recent communication on "The future of food and farming" that launched the discussion on the post-2020 CAP, the European Commission (2017) states that, even if the EU agricultural sector cut GHG emissions by 24% since 1990, it is unlikely that European agricultural emissions will continue to decrease at the same pace with the current policy support. This motivates why, among the four objectives including of the new CAP, the EU Commission includes "bolstering environmental care and climate action" emphasizing that a further effort is needed in this respect: "*Any new CAP should reflect higher ambition and focus more on results as regards resource efficiency, environmental care and climate action*" (European Commission, 2017: 9). At the same time, however, it is not clear how more ambitious goals will be pursued, that is, by maintaining and eventually reinforcing the current instruments and measures or by introducing new ones.

According to several analysts at this stage "*there is a huge disconnect in the Communication between the insistence that environmental and climate objectives will be given greater priority in the new CAP and the lack of any specific commitments*" (Matthews, 2017). In practice, despite the ambitions, the document seems quite conservative. It "*continues the shift of agricultural policy towards societally acceptable agriculture that has been occurring since the Fischler 2003 reform*", on the one hand, without proposing any "*real novelty as compared to the Fischler and 'greening' CAP reforms, but merely a reformulation of the same substantive framework using new terminology*" (Erjavec, 2017), on the other hand.

According to these arguments, the results of the present analysis can be quite informative for the current debate on present and future structure of environmental action in the CAP. They indicate that while the decoupling of payments tends to associate to better emission performance, this does not occur for the second pillar voluntary measures. This would suggest that, more than with ambitious voluntary measures, the overall objective of a stronger emission reduction could be obtained by letting the farmers pursue eco-efficiency with the large flexibility required by the very heterogeneous conditions in which they operate.

In his communication on the future of the CAP, the EU Commission proposes the elimination of the Greening Payment in favor of a new mandatory conditionality of direct payments and that will become the baseline for more ambitious voluntary practices. According to the present results, these instruments may fail in giving farmers all the flexibility they need to pursue, at the same time, the improvement the production and emission efficiency. On contrary, it is now largely agreed that improving eco-efficiency is often the most cost-efficient way of reducing environmental pressures. Moreover, for policy-makers it is easier and more acceptable advocating win-win policies that target improvements in eco-efficiency rather than imposing more radical measures that eventually imply a decrease of the farming activity. Indeed, this kind of policies can help farms in operating in the frontier of economic efficiency, creating net cost savings in addition to reducing their environmental impacts (Kuosmanen and Kortelainen, 2005; Ekins, 2005; Picazo-Tadeo et al., 2011; Coderoni et al., 2015).

At the European level, the concept of eco-efficiency has gained much policy relevance over the last years. In 2012 the European Union (EU) launched the Innovation Partnership for Agricultural productivity and Sustainability (EIP-AGRI) (European Commission, 2012) that should help addressing the need to increase production (to face the expected growth in global food demand), while conserving natural resources and the environment (Foresight Report, 2011; Esposti, 2012). The present study seems to support this kind of active policies helping farmers pursuing eco-efficiency, thus higher CP, instead of measures paying them to take choices and behaviour that do not take enough into account their heterogeneity and the specific condition in which they operate.

Needless to say, deriving policy implications informing the debate about the current and future CAP from an empirical study on a policy reform that took place 15 years ago (FR) requires caution. Many changes occurred within the environment where EU farmers operate. In particular, compared to the period analysed, market conditions changed so much that some authors suggest a substantial paradigm shift from abundance to scarcity (Esposti, 2017c). At the same time, agricultural technology also remarkably improved with the increasing availability of greener techniques especially concerning high-emission activities, like animal husbandry.

Therefore, the conclusions of the present investigation should be confirmed with respect to this new external context and within a more complex modelling of farmer's choices. The analysis should be replicated as soon as data on the current programming period will be available also to take the several changes occurred with respect to the FR into account; in particular, the impact on the abolition of milk quotas and the introduction of the Greening Payment. It remains true, however, that the present study indicates that any novel empirical evidence in this respect requires a farm-level investigation in order to account for the heterogeneity in conditions and behaviour typically affecting the agricultural sector. Aggregate studies disregard this heterogeneity and, therefore, might eventually lead to misleading policy suggestions.

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